INSTITUTION OF CIVIL ENGINEERS.

THE COMMERCIAL AND TECHNICAL RELATIONS OF ENGINEERING DESIGN AND WORK.

FRAME THOMSON LECTURE: 1911.

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FRIDAY, 28th APRIL, 1911.

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SIR JAMES INGLIS, Past Pres. Inst.C.E.,
in the Chair.

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Supplementary Note by the Lecturer.

A very important item of commercial value in an engineer is a conversational knowledge of foreign languages, more particularly Spanish and French. It is probable that in the near future the greatest scope for engineers outside of English speaking countries will be found in the great Central and South American Republics. In these countries Spanish is the universal language (except in the case of Brazil, where it is Portuguese, a language very closely resembling Spanish). At the outset of his career no engineer can tell where his best opportunities will arise. By a knowledge of Spanish and the geographical and commercial facts regarding the Central and South American Republics, he more than doubles his probable sources of employment.

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DR. TUDSBERY, M.Inst.C.E., Secretary of the Institution.

The Chairman:—

You have assembled here this evening to hear a lecture upon "Commercial and Technical Relations of Engineering Design and Work," by Mr. Frame Thomson. We are accustomed to meet you here from time to time to introduce lecturers and to discuss purely engineering subjects, but this is a somewhat interesting occasion, because I may fairly say that this lecture is the first of what I hope will be a series upon the financial results of engineering operations and the necessity of keeping the commercial principles in view when designs of engineering works are being made. Mr. Frame Thomson, like myself, is an old student; I suppose he began in the same rough and tumble school and had to justify his existence. That he has done abundantly, and he comes now and says that these principles which he has been exercising have stood him in good stead. He says, in effect, "I feel as I go through life I can face my employers with confidence from the fact that I make it a principle to see that my clients get at least 5 per cent. on their investment, and not only that, but get a structure which will last as well as design can make it last." Mr. Thomson, original in most things, has, as you know, purchased an annuity, dependent on his life, and the proceeds of this annuity will go to secure good lecturers and enable steps to be taken to make the series of lectures effective during his life. He hopes that after he has gone, some other student will do much the same thing. I must not hinder you any longer, but will ask Mr. Thomson, who has shown an originality and an earnestness in impressing his views on those who are younger than him, to give us his lecture, which, I am sure, we shall all be delighted to hear.

Mr. Frame Thomson :—

Before I commence my lecture I ought, I think, to place in the proper quarter the credit for the originality which Sir James Inglis has attributed to me. My idea was the very simple and old-fashioned one of providing a sum which, not at the exorbitant rate of 5 per cent. which some of our friends are accustomed to expect, but at the more moderate rate of 4 per cent., would yield the required annual amount; but our Secretary, with that true desire to promote the interests of the Institution which he always has at heart, suggested that it was much more desirable that these foundations should be in the form of life-annuities, because on the termination of the life of the individual founding them there was a gap for someone else to step in and fill, whereas when these things are made permanent those who wish to do something for the Institution find no opportunity of doing it. I think that little suggestion on the part of Dr. Tudsbery shows in a very marked way the manner in which he keeps the vitality of the Institution always before him.

As something of novelty in the history of the proceedings of the Institution attaches to the subject that brings us together this evening, I am sure you will forgive me if I begin with a few words upon the circumstances which have led up to, and the ideas which have crystallised into the foundation of this series of lectures.

During the past century the practice of engineering passed from the rank of a craft to that of a profession, involving studies of a highly scientific character and requiring in its votaries a sense of strict probity commensurate with the magnitude of the interests entrusted to them.

Its rise to this high plane was accompanied by the growth of a prejudice common to all those classes of society whose distinction from the general body of the population has had its origin in superior qualities of mind and character. The attitude of contempt or indifference towards commercial matters on the part of members of the military, clerical, legal and medical professions is too well known to require more than a mere reference in illustration of this feature of society in all ages and in all countries, with the possible exception of those whose attainment of a high rank among the nations has been coincident with the intense industrialism of the past half century.

The principles upon which the Institution was founded and has been conducted have naturally drawn into the circle of its greatest activity those members of the profession who represented in the highest degree the embodiment of its distinctive qualifications. It was to be expected that in an atmosphere so created the intrusion of commercial considerations into the proceedings of the Institution should be regarded with suspicion as having something of a sordid taint attaching to them. But each decade has seen the application of the forces of nature to the use and convenience of man flood new territory and bring the engineer into direct and personal contact with the avocations of every class, trade and profession. The increasing intensity of life tends to widen more and more that particular sphere of his energies in which the only justification for his work is that it shall produce a profit upon its cost, or at the least shall not cause a drain upon other resources than its own revenues. These considerations have aroused in many minds the feeling that the young engineer has not been given a really fair start in life if his attention has not been directed to the necessity for supplementing his technical studies with some knowledge of commercial practice and principles.

By a chain of circumstances, separated by long intervals, the good fortune has fallen to my lot of being permitted to inaugurate a modest effort to bring and keep this point of view before the students of this Institution. As these circumstances are closely related to the development of the student class, I am sure you will not attribute to mere egotism my desire to place them on record in this introductory lecture.

Twenty-eight years ago, a few pupils and assistant engineers in Glasgow conceived the idea of meeting together regularly and debating engineering questions, under the name of the Glasgow Engineering Association. The debates were keen and well supported. As might be expected in so active a centre of commerce, the subjects treated were chiefly those relating to works whose function was to improve commercial facilities, and whose chief virtue in the eyes of their owners was that of yielding a handsome profit. The Glasgow merchant or banker, and he is only typical of the merchant and banker everywhere, does not invest in engineering enterprises for the purpose merely of encouraging science and art.

Most of us were Students or Associate Members of the Institution, which led to the desire to dissolve our separate association and establish our proceedings on a firmer basis under the ægis of the Institution itself. The result was the formation of the first Local Association of Students. It was followed by others in various parts of the country.

In 1892 and 1893 I had the honour of filling the chair of the London Students' Committee, whose functions at that time were limited to organising the Annual Dinner and promoting social intercourse among the Students, and I well remember the bitter jealousy with which we regarded the autonomy of the local associations in respect to their affairs in general, and the persistence with which we urged upon Mr. Forrest our claims as London Students for some such self-governing powers. Years afterwards this desire ripened into fruition, and the London Students Committee was given an official position in the organisation of the Institution. By a purely accidental circumstance the opportunity was given me of presiding at the meeting that elected the first Committee. Representing, as it did to me, the culmination of twenty years' development, in all of which I had taken some part, the occasion impressed me very deeply, inspiring me with the desire to give tangible expression to my feelings.

The result of many conversations with our esteemed Secretary, Dr. Tudsbery, was crystallised into reality in the form of this series of lectures by the Presidential Addresses of Sir James Inglis, than whom the Students have never had a kinder or more devoted friend. I am sure you will join with me in taking this opportunity of expressing to the Council of the Institution our appreciation of the warm interest they have always shown in the welfare of the Students and of the further proof of that interest given in their consent to the establishment of these lectures. For myself, I wish also to express to Sir James Inglis and to Dr. Tudsbery most sincere thanks for the valuable assistance and advice which they contributed to the shaping of the idea.

It is not my intention this evening to attempt a careful treatment of any of the details of the commercial knowledge which you are to be encouraged to study. I shall rather try to open out to your view the general aspects of the subject leaving to subsequent lecturers the treatment of those branches which their special knowledge will enable them to deal with as experts. I shall not even pretend to offer you a coherent and logical address, but rather a collection of ideas and suggestions, as they have occurred to me, bearing upon the matter in hand.

One of the most valuable mental faculties for creative work, whether tangible or intangible, is a properly cultivated power of imagination. On the technical side of engineering this is so obvious as to be a mere platitude. The ability to form a correct mental picture of the structure required to obtain a given result, not only cuts out a vast amount of tentative work by directing the mind more or less into the most suitable channels of study, but also gives its possessor greater confidence in the final outcome of his investigations. Applied to commercial and industrial questions, it lifts them above the pounds, shillings and pence point of view of the shopkeeper, by enabling the mind to grasp them as realities of the social and economic machine, and to see behind and beyond the mere rows of figures by which they are defined. That is a point of engineering which very few engineers pay sufficient attention to. Practically every kind of engineering work must in one form or another affect the social conditions of some part of the population, and unless that ultimate result is properly kept in view, with proper relation to its earning capacity, there is bound to be friction between the authorities who represent the interest of the public and the capitalists who provide the money with the intention of making a profit. I am happy to say that all over the world the interdependence is becoming more and more recognised, and the sharp lines which separated capitalists from public authorities are not now so distinct.

The name of the late Lord Goschen is a household word in commerce and finance, but the cultivation of correct imaginative power had no more strenuous advocate than he.

At the risk of irrelevancy, I shall quote a few of his remarks in this connection:—

> * "I wish to speak to-night on behalf of the cultivation of the imaginative faculties in the broadest sense of the term; and I am not afraid to speak thus before a Liverpool audience and as a business man, because I will not admit an antagonism between business and cultivation; I will not admit that the cultivation of the imaginative faculties disqualifies men and women for the practical duties of life. Indeed, I hold that the cultivation of the imagination amongst all classes whom such an education can reach, is not only important to the young themselves as increasing their happiness, but important to the nation as qualifying them to become better citizens and fitting them to take a useful and noble part in our national duties.
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> "In what sense, then, do I use the word imagination? Johnson's Dictionary shall answer. I wish you particularly to note the answer Johnson gives as regards the meaning of 'imagination.' He defines it as 'the power of forming ideal pictures;' 'the power of representing absent things to ourselves and to others.'"
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> "Imagination, in the sense which I have described, is necessary everywhere, and perhaps we have too little of it now in a great many departments of life; and I will tell you why. Because we are all too much oppressed with detail; because, in the study of detail, and in the study of useful knowledge, we frequently too much ignore and too much

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* From an address delivered before the members of the Liverpool Institute, Liverpool, November 29th, 1877.

forget the broader lines of study, and the more important generalisations which neither statesmen nor electors, nor indeed any class, ought ever to lose sight of."

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* "This constructive imagination takes its start from facts, but it supplements them and does not contradict them. It is a faculty the conceptions of which probably present truer pictures than those afforded by knowledge of facts alone—vivid, truthful pictures, which knowledge of facts alone would not enable us to paint.

"Perhaps I may be best able to illustrate my meaning if I contrast this creative imagination, this power to construct or re-construct, with the faculty of analysis. The operation which I have in my mind is the very opposite of analysis. Analysis eliminates, separates, strips off, reduces. Analysis discards temporary conditions and surrounding circumstances, and reduces what is under examination to its simplest form. Analysis in Economics seeks to discover the general principle by what may be called the destructive process. It has, I admit, a fascination of its own.

"The function of constructive imagination, on the other hand, is to proceed in the opposite direction. Its work is, by an effort of the mind, to realise and depict what is not present to the sight or palpable to the touch.

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"When you go forth into the world, armed with the intellectual instruments which you have forged and sharpened during your University career, with your minds stored with acquired knowledge, and equipped with all the capacities for future accumulation, do not think that you can afford to discontinue its use. Its vigorous employment will check that intolerance which sometimes springs from the premature dogmatism of confident youth, sometimes from the fanaticism of its too enthusiastic beliefs. Intolerance and fanaticism can more satisfactorily be restrained by that wholesome imagination which vividly realises the thoughts and feelings of other men, than by that infusion of scepticism which is one of the most pernicious drugs of the age. Let intolerance, which is the child of absolute personal conviction, be not simply checked by undermining that conviction through the negation of the existence of positive truth, but let it be softened by the habit of studying and realising to ourselves the counter-theories of men who think differently from us.''

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* From the Rectorial address delivered at Edinburgh University, November 19th, 1891.

But the value of imagination in business is not limited to the greater efficiency and rapidity with which it enables analytic and synthetic methods to be applied; perhaps its greatest value is the added interest which it gives to every problem, so that the work involved in its solution becomes an engrossing pleasure. Regarded in this light, the commercial aspects of engineering are devoid of any sordid element, and can take rank with its technical aspects as deserving of respect and admiration. I have seen more than one instance of the successful development of a great conception being accompanied by large profits, even considerable fortunes; instances in which I can vouch from personal knowledge that the driving force was sound and correct imaginative power, and the monetary consideration the ballast which steadied its action.

At the risk of appearing to labour this branch of our subject, I feel bound to emphasise it in the strongest terms at my command. The object of these lectures would be hopelessly perverted if they tended to lower the ideals of which every engineer is proud. On the contrary, it is my earnest hope that one of the results will be to impress upon you that permanent commercial and financial success not only may, but must, be based on the same principles of reliability, efficiency and security that you apply in your technical work. It is not true that either commerce or finance are disreputable either in their objects or their methods. There have been and are dishonest merchants and financiers, just as there have been and are dishonest engineers. But if we believe, as we do, that the great majority of the members of our profession are devoting to it the best of their ability and energy, and for objects beneficial to the community, so also we must believe that those other two great classes of society are chiefly composed of men like ourselves, animated by the same principles and engaged in operations not less worthy than our own. To have a sufficient and intelligent understanding of the principles and practice underlying their operations, so that where our work is precedent, parallel or supplementary to theirs, we may adjust it to produce the greatest combined efficiency, is no discredit to an engineer. On the contrary, the absence of such working knowledge prevents him from pulling his share of the load, and imposes needless difficulties and risks upon the other units of the team. Not only so, but the very nature of an engineer's training and instincts provides him with many of the habits of thought and action which are essential to the soundness of commercial and financial operations. He is imbued with the importance of painstaking investigation of all essential detail and the avoidance of non-essentials, with the importance of a large factor of safety, and with the necessity of provision for unforeseen contingencies. All these make him a valuable collaborator, provided he is possessed of the working knowledge to appreciate their application to other activities than his own purely technical branch.

All our studies, whether in college, field or office, are directly or indirectly a portion of the great evolution by which the application of natural forces has progressed from the titanic manual structures of the ancient pyramids swarming with the hands that laid piece by piece in place, to the modern leviathans and mammoths of sea and land whose tremendous forces obscure into insignificance the puny hands controlling them. We have studied the slow and generally hesitating steps by which great aggregations of human labour have been gradually superseded by an equally stupendous concentration of mechanical power into small compass. We are familiar, each in our special sphere, with the physical, mathematical and chemical laws upon which the success of our individual branch of work depends. But how many of us, I wonder, have left the recognised paths of technical study to wander in the field of the economic and commercial forces whose evolution has been not less marked, though less observed, than the others, and whose influence upon the progress of our profession has at all times set the ultimate limit to effort.

In the towering masses of the pyramids we see sterile accumulations of capital representing surplus labour forced from the ancient slave; the Lusitanias of to-day are the fertile embodiment of capital created by the thrifty savings of the surplus labour of free men. In these two extremes we have the key to the essential difference between the economic and commercial conditions governing the work of the engineer of the past and him of the present day. From the forced labour of the slave, down through the military service employed on the Napoleonic roads, and the assessment roads of the Telford period, to the investment of private capital for profit in the modern railway, we see the gradual change in the engineer's position relatively to the resources at his disposal for constructive work. In the early days these resources were placed at his disposal by the compulsion of authority without consideration of fertility in the result, to-day he has to sue for them and to prove that his creation will be a living organism whose growth is expressed in the word profit. In the specialisation and complexity of modern conditions we are apt to lose sight of the elementary basis of many of the expressions we use. This I think is the case with most people as regards the word profit, which after all is no more than a synonym for increment of capital. The profit of a harvest is the excess by which the value of the crop exceeds the cost of the seed and the expense of the operations. The seed and the expenditure are the capital invested, the value of the crop is the capital realised, the difference or increment is the profit. To secure a profit the organism must be capable of growth. In the earlier stages of the development, which I have outlined above, this consideration of growth was absent; the resources were provided by the compulsion of authorities whose only consideration was that the work be done, and that it be stable. The engineer carried out his work with a lofty indifference to the cost, then represented merely by the surplus labour of so many individuals. By surplus labour I mean the excess of which they were capable, beyond that required for their bare sustenance. Gradually the elements of restriction in the quantity of labour available and the necessity for paying wages imposed upon the engineer the obligation of balancing the means to the end, but he was still free of any consideration of life and growth as conditions of his work. To-day he has reached the maximum of complexity in having not merely to balance stability and cost in his calculations, but also to provide for the permanent life and growth, without which his work offers no attraction, in the majority of cases, to those upon whom he is dependent for the resources to create it.

This short abstract of the general course of engineering economics in one of its aspects brings out very clearly the transition from a state of things in which waste and the sterile application of labour were matters of indifference, to the modern condition in which the ultimate test of the engineer's production is the absence of waste and the presence of fertility.

Stagnation is a condition inconsistent with the life of a healthy organism. Growth and decay are the active manifestations of life. By the prevention of decay and the stimulation of growth maximum efficiency is obtained. The surest way of obtaining profit is to prevent loss. Any enterprise that is radically sound cannot help growing (that is, making profits) if every element of waste and loss can be eliminated. As a general rule men's minds fasten more readily on the attractive possibilities offered by the prospect of stimulating the growth of an enterprise than upon the more prosaic feature of stopping all possible leaks. Stated in order of importance, I consider the main factors of success for an industrial enterprise to be:—

1. Safeguard from waste.
2. Provision for expansion.
3. Stimulation of growth.

These considerations may appear at first sight to be more properly within the functions of the operating engineer than of the designer and constructor, but a moment's thought will show that as the former has to work with the equipment provided by the latter, his work will be either facilitated or handicapped by that equipment. Consequently, the designer and constructor, to be of the greatest value, must think backwards from the field of action of the operating engineer to the starting point of their own problems.

One of the most valuable features of design, from the point of view of assistance rendered to the operating man, is that of adaptability. By that I mean keeping in view in all parts of a design the probability that its working conditions will not conform precisely to the forecast upon which the design is based, and if the design does not or cannot be subjected to modifications during or after construction without excessive expense, the operating engineer will be hampered in successfully applying it to the work to be done. One of the simplest illustrations of adaptability is that of providing ample space, not merely for growth by extension of works, but for improvement within the limits of the original work.

Simplicity and the use of standard appliances and materials are very important qualities in a design considered commercially. By keeping the design down to the simplest elements compatible with efficiency, the variety of spares to be kept in stock is reduced to a minimum, whilst the use of standard articles, which can be obtained on short notice by letter or wire, keeps down to a minimum the amount of dead capital lying idle in the form of stock at any given time, and reduces the time during which it is lying dead, thus saving the interest upon it. A very well-balanced judgment is required to draw the line where economies resulting from increased complication, as, for example, a multiplicity of auxiliary plant for accessory purposes, detract from instead of adding to the efficiency of the entire combination. On the whole I have personally always favoured simplicity, even to an extent that may seem to involve some apparent extravagance, say, for example, in the coal consumption of a power station, because I have felt that the human element in the supervision and control of the plant is quite as large a factor in the final economy as the mechanical equipment through which it operates. There is a certain limit of complexity, different, of course, in each case, beyond which the mental effort required to keep continually feeling the pulse of the various elements is too great for the average man; in the words of the late Lord Goschen, he becomes "too much oppressed with detail." When the controlling mind is overburdened, loss of efficiency is inevitable, and just as worry produces physical inefficiency in the body, its counterpart operates similarly in the organism whose muscles are of steel or copper and whose blood is steam or electricity. The engineer is faced with no more difficult problem than the personal one, and in solving it a well trained imagination plays the leading part; an imagination which, again to quote Lord Goschen, "vividly realises the thoughts and feelings of other men," and not only their thoughts and feelings but their limitations; which can, in fact, not merely realise their feelings, but puts its possessor into the position of *feeling as they do.*

You may be inclined to ask me what all this has to do with the commercial aspect of engineering work. What I have just been saying has had the object of illustrating by a line of thought with which your studies and reading must have familiarised you, the central feature of my remarks to-night, viz., that the perfection of engineering detail falls short of your whole duty if it is not accompanied by a judgment and imagination capable of appreciating the non-technical conditions which, in the end, control and limit its scope in each case. I have led you up to the appreciation of one of these, the human or brain element in the engineering organism, which is already familiar to you. But your contact with the human element does not end with the labourers, foremen, superintendents and managers. Behind and beyond all these, too often separated from them by an empty void, are the brains whose financial ability secures the means by which your works come into existence. Like yourselves, these brains work on formulæ derived, consciously or unconsciously, from experience, by rule of thumb, and the lessons of trial and error, or by processes of logical analysis quite as rigid and sound as your mathematical studies. The functions of their formulæ are capital and profit; their great common denominator is money. What we have all to realise is that, just as much as steel and concrete, money is one of the things we have to deal with in engineering structures. In the initiation of an enterprise they rely upon you to provide them with estimates of first cost, probable earnings and probable expenses, in which the elements of chance or guesswork are reduced to a minimum. They rely upon you to gauge the unforeseen contingencies, and they rely upon you to have qualified yourselves, by your own experience, by voracious assimilation of the experience of others, by painstaking analysis and synthesis of these experiences, to probe the innermost recesses of the enterprises upon which you have to pass judgment, and further, perhaps most important of all, to be able to lay the results before them in terms not merely intelligible to them, but so intelligible that they can themselves criticise your deductions and be convinced in their own minds, and by their own judgment, of the soundness of your conclusions. To an experienced engineer, thoroughly saturated with the physiology of his special branch of the profession, the process of forming a mental picture of a project, though involving laborious work, is almost automatic, and the resulting picture is clear and sharp to his mind. The real crux of his difficulty is the effort of projecting into the minds of his associates that same picture with sufficient clearness and sharpness. I am quite aware that I am putting before you an aspect of your duties which, as a general rule, is not demanded of the engineer. Just as the average solicitor is content to cover his own responsibility by submitting his client's case to counsel, so the average financier is similarly content to take the engineer's report as read. For myself, I have never been satisfied to have my expressions of opinion taken as final and conclusive; on the contrary, I frequently put them forward in such shape as to compel criticism from those for whose use they are intended, so that they may have the double satisfaction of arriving at a firm conviction and of realising that it has been reached with their collaboration, and not taken for granted. For myself, this process has the great advantage that it provides a valuable check and supplement to my own study of the matter, by bringing to bear upon it the trained intelligence of men who look at it from the point of view of their own wide experience in other directions than my own. To be fruitful it implies, of course, that one's associates are not mere guinea-pigs, but men of keen commercial knowledge and sense of their own responsibility. It involves also a very much greater effort in constructing a lucid exposition of the subject in terms of the special branches of experience which it touches, and the use of much tact and patience and time. And it is precisely in such relationships that the engineer finds the greatest value in general commercial knowledge. For such purposes as I am now dealing with he must be able to look at business with something of the spirit of the banker, the "adventurer" in the good old commercial sense of the word, the lawyer, the accountant, the stockbroker, the municipal councillor, the Minister of State, and even the Head of the Nation, so many are his points of contact with human activities. I am not for a moment advocating that you should be jacks of all trades and masters of none. But I do advocate that you should be *pastmasters in the art of taking pains*, and whilst your greatest pains should be devoted to the mastery of your own profession, a suitable proportion of your time and ability and labour should be devoted to making yourselves familiar with the methods of work and ways of thought of other professions and businesses.

But generalities are a very easy and comfortable way of filling out an address, and leave the hearer much where he was before if they are not crystallised into some practical suggestion. An ounce of practice is to-day worth just as many pounds of theory as it has always been, probably more, as theory to-day is more easy of access and less laborious in acquisition. If you will permit me, I shall indicate shortly from my own experience how I obtained such little commercial knowledge as I possess, and which I can assure you I have found to be of immense value, not so much in itself, but for the reason I have been harping on all the evening, that it enabled me to picture to myself the point of view of my associates in business.

Whilst I was serving my apprenticeship as a civil engineer I attended on two successive winters' series of evening lectures on mercantile law. These were delivered by a brilliant young solicitor, who dealt with the general principles upon which mercantile law has been evolved. Treated in this manner it was no dry-as-dust exposition of cases and rules, but a fascinating progress through a living territory of thought. It left the mind saturated with the essentials and burdened with no more detail than was necessary to show the reality and practical application of the principles. Don't get the idea into your heads that any smattering of law which time will permit of your obtaining will justify you in acting for yourself in matters which are the province of the lawyer. A little knowledge is a dangerous thing if it inspires presumptuous self-confidence. One of the great benefits of a little knowledge of law is that it opens out to your view many pitfalls of which you would otherwise be unconscious, and provides a danger signal warning you to secure sound legal advice when you might otherwise blunder into serious errors. No engineer, however subordinate, is devoid of contact with some and probably many contracts. If he is entirely ignorant of the principles of law relating to contracts, as, for example, the legal value and effect of verbal understandings, verbal modifications of written agreements, or written modifications of agreements under seal, he may very well find that precautions he had taken in such connections crumble away from him in a court of law or arbitration like so much rotten timber. We all have to use cheques, and most of us at some time or other come into contact with bills of exchange, telegraphic transfers, and problems of foreign exchange, all of which have a legal side that is important for us to have some familiarity with. The law of evidence and its various degrees of stringency, as, for example, in arbitration, as compared with courts of law, is one that touches us at many points. The laws relating to common carriers, land purchase, railway rates insurance, shipping matters, and many other subjects, come at one time or another within the horizon of most of us.

As regards book-keeping and accountancy, I happened to come across in a magazine article a suggestion that practical experience of a very useful kind can be acquired by the simple process of keeping track of one's own personal expenditure on the regular double-entry lines. What I am saying to you may appear small and insignificant, but these are little things which every young man can do for himself, and if you do them long enough they cease to be small and insignificant. The idea struck me as ingenious, and for many years, until other interests and occupations made it superfluous waste of time, my expenses on lodging, food, clothing, cabs and the many other items of daily expenditure went through a process of accounting from day to day, and an annual audit as rigid as the most stringent chartered accountant could desire. In carrying out a contract, or in supervising a contractor, your position will be immensely strengthened if you can, yourself, intelligently understand and trace out the ramifications of the various accounts, analyse them in such a manner as to bring out the particular feature you require to ascertain, and recast them into statements which check up at all points with the accounts themselves, but go further than the accounts in showing the grouping of expenditure or receipts so as to throw important sidelights on special aspects of cost or revenue. Especially important is this faculty in relation to the operating accounts of commercial and industrial enterprises. The real inwardness of their position can very often only be ascertained by grouping the items of their accounts in half a dozen, a dozen, or even two dozen different ways and noting the comparisons so obtained. In these matters there is no more effective solvent than the ability to represent the course of expenditure and receipts graphically, and your familiarity with this method of synthesis and analysis in your technical studies provides you with a valuable means of tracing out problems, based upon accounts, if you know enough about accounts to be able to apply your experience of graphic methods. We are all called upon from time to time to make reports involving either statements of past results of working or forecasts of the future, and for such purposes the graphic method is by far the most reliable, as it brings the eye to bear as a check upon the pen. In such connections you will find that calculators of various kinds are a great help by eliminating the drudgery of arithmetical repetition, and thus leaving your mind fresh to follow up the line of thought, for which the calculations are merely buttresses. By a free use of all labour-saving devices you will find that you can not only do more work in a given time but do it better and with more confidence, because of the greater ease and facility with which your mind can direct it.

Later on, when a little superfluous cash created the opportunity, a capital and investment account made its appearance. I think it started with £20 of 4 per cent. preference shares in a small company in Glasgow, but with the progress of time its borders swelled so that it has touched the fringe of practically every kind of share or bond, from consols through the gamut of railway, steamship, tramway, industrial and mining companies. In the course of its growth, practically every problem of investment fell within its scope; traffic returns were watched, balance-sheets and profit and loss accounts studied, methods of treating increment and depreciation were developed, realisation and reinvestment problems arose, and generally, in a small but comprehensive manner, there came up for consideration most of the problems connected with the business of the investment of capital. It does not require a man to be a big capitalist in order to have a share in twenty companies; you can buy a £1 share in twenty companies for £20. By this means I acquired without much expense a considerable knowledge, not only of the pitfalls awaiting the unwary investor, but of certain general principles underlying the successful control of capital. All the factors I have mentioned turn up together or separately in connection with enterprises built for profit, and the engineer who makes estimates of results without having realised the bearing of such questions as depreciation and renewals, discount on the issue of securities, sinking funds for redemption of capital, will soon find that "facts are chiels that winna ding," and, to mix the metaphors, come home to roost in very disagreeable guise. Knowledge of "the sweet simplicity of the Three per Cents" is a poor equipment for a man who may have to advise upon the prospects of enterprises ranging in security from the humdrum stability of a loan with the guarantee of a Great Power to the mercurial attractions of a new mining development. If you take the trouble to note from time to time the brilliant forecasts of the engineer's reports embodied in railway or other industrial prospectuses, and keep a lookout for the subsequent results when the enterprises get under way, you will realise that even the glamour of a Westminster reputation will fail to avoid disaster to schemes commercially defective. Or if you will occasionally take up the balance-sheet and Profit and Loss Account of a railway, tramway or industrial company, which are all things you can get for nothing, and get an accountant friend to explain it to you, you will be astonished at the new light such studies will throw upon the principles of industrial operations.

No amount of care or study will absolutely guarantee success for any enterprise, but care and study intelligently applied will at any rate reduce the adverse contingencies to the limits of ordinary business risks. And that is all our clients ask from us. They do not want impossibilities. On the contrary, they want us to make our studies sufficiently carefully, and when we can prove to them they have been made carefully enough they do not blame us for what goes wrong afterwards. That is simply the ordinary business risk and is covered by the surplus of successes over failures. They may even make all the difference between success and failure, as has been proved over and over again in cases where water-logged concerns have been pulled round and set on their feet by men capable of seeing the defects and applying the remedies. The trouble is very seldom on the surface, and it is very rarely due to any one kind of cause. The construction may be good of its kind, the management may be good of its kind, the accounting may be good of its kind, the financing may be good of its kind, but they may each be just sufficiently not of the right kind for the purpose, to produce weird results. To correct such a situation, or to foresee and prevent it, obviously requires some knowledge of all these elements, and not merely complete knowledge of one of them. Or, again, in the case of inventions which you may originate or be asked to report upon, it is of the greatest importance that your keen appreciation of a bright idea should be qualified by some understanding of the obstacles and difficulties which lie in the way of its practical application, and of the conditions of working essential to its establishment as a going concern. I have seen many instances of the waste and loss caused by want of commercial knowledge on the part of clever inventors. One of their most common errors is that, when they have induced their friends to provide money for its development, instead of pushing on the production and sale of their article they exhaust the capital in continual attempts to improve it. The result is that the money and time which would have enabled them to obtain a firm market for an article sufficiently good is frittered away in experiments for improving it, and the whole thing ends in recriminations and failure. Incidentally this reminds me of a very important relationship between time and money. When capital is being expended upon an asset that will become revenue producing it is usually profitable to spend it as rapidly as possible. Every month's delay in construction means a month's loss of revenue, so that methods of construction which save money at the expense of loss of time must be very suspiciously scrutinised, and, on the other hand, methods which save time at the expense of money should be studied with a very friendly eye. Loss of time is a two-edged sword, it cuts into profits, both by loss of revenue and by increase of interest and general charges. Extra cost to save time increases interest charges, but gains revenue to offset them, besides saving general charges. Spending money is not in itself extravagant, it is often the greatest economy.

I should be lacking in the most elementary sense of gratitude if I seemed to claim for myself the credit for the turn of mind which led me to follow these by-paths of commercial experience, or failed to take this opportunity of expressing my deep sense of indebtedness to Mr. John Strain, Vice-President of the Institution. As his pupil I enjoyed a training which was not only practical and thorough in railway engineering (than which there is no more comprehensive branch of the profession), but broad and wise in respect of such matters as contracts, specification and purchase of materials and equipment, and what I value most of all, in respect of the true economy which consists, not in buying what is cheapest in unit price, but what gives the best value for its cost, having regard to the purposes it has to serve. One of the greatest curses that our country suffers from to-day is the almost universal craze for getting everything as cheap as possible. It is a strange and painful anomaly that in a country like ours, whose manufacturers take the first rank in the world for ability and inclination to do the best work and give the best value for money, they should be handicapped and disheartened by forms of competition which are the offspring of this vicious principle of cheapness at all costs. It is as inevitable as any of the natural laws of the physical world that lasting economy can only be obtained by paying a fair price for a fair article. The strong position which our manufacturers still hold all over the world, in spite of their stubborn and inelastic methods in foreign countries, and in spite of the great inroads that have been made in their trade by the competition of cheaper products, is chiefly due to the widespread recognition of the fact that an Englishman gives better value for money in any article, the manufacture of which he has thoroughly mastered, than do his competitors. I cannot make this statement without coupling with it a reservation in favour of certain American manufacturers whose products, partly on account of wider experience and the greater opportunity which their great home market has afforded them, take rank with the best that we can show.

In concluding what has been but a rambling talk upon a few general features of a wide subject, I should like to urge upon you the belief that there is no kind of knowledge that does not find its niche of utility at some time or other in your careers. The habit of picking up and assimilating all sorts of information that present themselves will not only maintain your minds in a state of keen receptiveness, but will provide you at unexpected moments with just such knowledge as you urgently require, and which, but for such habits, you would be at a loss to know where to find. In a very special degree this applies to making copious notes of all information, wherever you find it, of the cost of work and materials. There is no notebook so valuable in the active period of an engineer's career as one containing every price, contract amount, detail of cost of working, or other form of data upon the relation between money and work, that he has come across in his earlier years. It is not sufficient merely to note these data and index them, you must expand them and reduce them to units of general application. The continual practice of this sort of thing provides you at length with something infinitely more valuable even than a vast collection of notes, viz., with an *instinct* for appraising costs by an unconscious mental process. This instinct when acquired carries you a great deal further than the limits of the special lines with regard to which your cost data have been collected. There is a subtle but very real analogy between the cost of work of different kinds and executed under different conditions, the appreciation of which is perhaps more of a natural talent than an acquired accomplishment, but is capable of great development by continuous assimilation of all available material respecting costs of all kinds.

In connection with this question of acquiring practical information of all kinds I will give you another suggestion from my own experience. For more than twenty years I have been a subscriber to the "Times." For twopence a day you can saturate your mind, year in and year out, with the knowledge of practically everything of consequence to a man who aspires to a broad and sound business position. You will acquire from its columns not merely facts and figures, but a sense of the political, commercial and social atmosphere in all important parts of the globe, and a fund of scientific, geographical, industrial and commercial information which will make you as nearly citizens of the world as it is possible to become without actual travel.

One or two points have been suggested to me by members of the Students' Committee, to whom I submitted the draft notes for this address. One gentleman has asked me to express my opinion on the following questions:—

When a student has completed his articles or college training should he—

1. Go to a contractor or a consulting engineer?
2. Go to a large firm or a smaller one?
3. Stay long with any one firm before the age of 25 or 27?
4. Specialise in any one branch before that age and to what extent?

The answers to these questions depend so much upon the opportunities open to each individual that they would probably vary very much in different cases; but, speaking generally, I think that a short period spent with a good contracting firm would be a most useful part of an engineer's training, as it brings him into more direct daily contact with cost problems, and if practicable it should precede his entrance into a consulting engineer's office. A smaller firm doing a somewhat varied business I should consider preferable to a large firm where the individual's work would be restricted to one part of the general routine. Experience with more than one firm is bound to be valuable, as the comparison of different methods will stimulate the faculty of observation. Specialisation in a broad way is inevitable nowadays, but the final specialisation into one branch of the profession is likely to depend more upon opportunity than selection, and should be postponed in most cases until some definite opportunity clearly calls for it. There are other considerations that affect an engineer's decision in such matters, such as the nature of the personal backing that he can command, and the extent to which he can choose for himself independently of making his living entirely on his own resources, but as a general rule I should say that up to the age of 30, breadth of experience rather than extreme specialisation should be his objective. In one of the leading articles of the "Times" recently the following expression occurred, which struck me as being relevant to this question:—"Inspection, if it is to be more than a useless formality, must be carried out by men whose experience is wider than that of the inspected."

I am dealing with these letters here because I wish the Students' Committee to feel that these lectures are part of the Student Organisation, and I hope they will endeavour cordially and heartily to make the accumulated results of the lectures a practical success.

In another of the letters I received from members of the Students' Committee the following passage occurs, which, I think, is worth quoting:—"It has often occurred to me that the young engineer does not, as he should, look at his work from a general point of view, and that in following certain rules he omits to also consider the course he would adopt if he were himself responsible for the work." I think the gentleman who wrote me that phrase hit off in two or three words one of the features of success, that a man should do his work as if he were himself responsible for the result.

The same gentleman regretfully chides me for not having included artistic considerations amongst those which should be adjunct to the technical aspects of engineering. I should be sorry to have spoiled the pitch for his reinforced concrete colleagues, who will doubtless seize with avidity upon a new argument in favour of their versatile product and establish a series of lectures propounding its merits as a thing of beauty and a joy for ever.

Having now trespassed too long upon your kind patience I will close these remarks with an expression of the great pleasure it has given me to renew my association with the Students of the Institution, and to feel that I am still one of them in spirit and enthusiasm if no longer in name.

The Chairman :—

You have by your applause anticipated the first duty which is down upon the Agenda for me to perform, and that is to move a vote of thanks to the author, and to call upon Mr. Samuel, the Chairman of the Students' Committee, to second it. I think you have heard in this paper to-night a sort of life record. There is enough in it for two or three lectures. It is very fortunate for us to feel that it is the beginning of a series which will draw attention to the points raised. It seems to me the great central idea of the whole paper can be put in one sentence: The voracious assimilation of the experience of others. That seems to me the central principle round which the whole thing revolves. Another reflection which these speculations bring about is that the more nearly men of technical education are taken to the bosom of financial experts or become financial experts themselves, like our friend the author, the better for this country. You cannot spend half your life making mistakes and successes and gaining experience begotten of trial and error without reaping some benefit, and I think there is no class of person who has more of that luxury in this world than the civil engineer. However, I must not say much about it, although I could go on for a good time. I will content myself by asking two of our friends who are in the position of taking a bird's eye view of our struggles to say something to you on the subject, after Mr. Samuel has seconded the vote of thanks.

Mr. Samuel (*Chairman of the Committee of London Students*):—

I am very glad to have the privilege to-night of seconding the vote of thanks to Mr. Frame Thomson. As Sir James Inglis has said, this is a new subject for a lecture at this Institution, but we see in the Minutes of Proceedings of the Institution that particulars of the costs of our big works have been often given in connection with such works, for instance, as the Birmingham Sewage Works and the Hudson River Tunnel. I think Mr. Frame Thomson has chosen a subject which is absolutely neglected by our universities and engineering schools. I may say that when I came out as a civil engineer the hardest branch of engineering I found to be what is called the commercial branch, and I am sure we are all very grateful to Mr. Thomson for founding this lecture for the advancement of commercial knowledge in engineering. We must also thank him for giving this first lecture himself, for indicating to us the manner in which he has gained his commercial knowledge, and for showing us a way by which we may try to follow him.

The Resolution was carried with acclamation.

The Chairman:—

We have here a gentleman we do not often have with us, a very great friend to, but a greater critic of, engineers, and that is our good friend Mr. Balfour Browne. A good many references have been made in the paper to the conditions under which all commerce and securities exist, and I am sure that all the senior engineers here have had the pleasure of being worried and harried and generally turned inside out on a good many occasions. Most of you, though you have not arrived at that stage of being harried by gentlemen who delight in doing it, and can do it, know Mr. Balfour Browne by reputation. I am mentioning his credentials for giving us a little outside advice. A great part of his life has been spent in criticising engineers' estimates and explaining that their schemes would result in collapse, but there is a sort of something about his criticism which we all enjoy. He has experienced the personal qualities of engineering which our friend has somewhat wrapped up in his paper, but which is a very important item in dealing with affairs, and I am sure if Mr Balfour Browne will give us a word or two we shall all be delighted.

Mr. Balfour Browne, K.C. :—

I daresay you know that when one of the great Churches proposed to canonize a saint they appointed a gentleman who was called a "Devil's Advocate," to say everything he could against the canonization, and as we have here to-night the "Pious Founder," I suppose I am appointed to say everything I can in criticism of his paper. Let me point out in this paper one or two matters which I entirely dissent from. First of all, the author pointed out that "the attitude of contempt and indifference towards commercial matters by members of the military, clerical, legal and medical professions is too well-known." I have been longing for commercial matters all my life; I wanted to be on the fringe of all those investments where you can put in £1, but I have never succeeded. Any of you gentlemen who may have read the preface to Mr. Bernard Shaw's admirable play, "The Doctor's Dilemma," will realise that the medical profession is also conducted upon commercial lines. The next matter I have to criticise is one I am sure the author did not mean to put in the way he has done. He says: "The only justification for his work is that it shall produce a profit upon its cost," of course looking at it entirely from a commercial point of view; but to-day I was connected with a great enterprise, the reservoirs at Staines, which are to supply London with water, and in that case it is the benefit to London, not the profit which is to be made, which is the leading consideration. Birmingham at the present time is expending out of its rates £64,000 per annum for its great Welsh Scheme.

In a sense, it is a profit, but it is not a monetary profit; it is the benefit that it gets from a pure water supply.* The next point I should like to criticise, is the use of imagination. Lord Goschen, whom the author quoted, meant it, I think, not in connection with commercial enterprise but in regard to the cultivation of the man. I am perfectly convinced that without a proper amount of imagination no engineer is worth his salt; he is not worth examining, because he is not a real man. But what I take the author to mean is that every man must have a certain amount of enterprise. If imagination means that, I understand it. I have seen too much imagination in connection with mining operations and other matters! But if the author means a proper amount of imagination, as Lord Goschen did, for the cultivation of the man, that is another matter. I hate the idea that we ought to be dubbed according to our profession. We should all be men first. No one is a capable lawyer or engineer without first being a man. Without that proper amount of imagination, education is not complete. I quite agree with the author that enterprise is absolutely essential. A forecast of the future is absolutely essential, but it must not be too sanguine. Enterprise depends of course upon one factor which is at the very root foundation of this paper. There would be no enterprise unless an institution which exists and which is seriously threatened at the present time—private property—also exists. Imagination will be of no use in a Socialist State. The lecturer referred to forced labour on the pyramids as compared with the "Lusitania," which is a useful instrument of commerce. I am not quite certain that he is doing justice to the ancient Egyptians, because I cannot believe that the pyramids were so useless as they seem now; in fact, I believe that astronomers are still of opinion they have some real connection with the problems of astronomy. But Mr. Frame Thomson went a little further. He favoured simplicity. That was one of his beautiful sentiments I admired very much; it reminded me of the heathen Chinee who was childlike and bland. Now what the author counsels is excellent advice. You are not only to know all about commerce; you are not only to start with £20 and have 4 per cent. on it but you are to be on the fringe of all good investments! Further than that, you are to know a great deal about commercial law. I think he knew I was on his right hand because he said you were not to be your own lawyers but to consult lawyers occasionally. Then you are to be accountants; in fact, you are to know something of everything. That is a most excellent piece of advice and I would second that motion. Of course he is right. If you are to connect your engineering with economic considerations, you must, to a certain extent, be a bit of an accountant, and you ought to know something about law, the laws of evidence, of contracts, and other things of that sort; but at the same time you cannot all be specialists. It is impossible to be a specialist in everything, and you are to be specialists in engineering. At the same time a general knowledge will, as the author has pointed out, be of admirable service to you in your profession. Now when he came towards the end of his lecture he spoke of the almost universal craze for getting everything as cheap as possible. Further down he spoke of the advantages that America enjoyed in connection with her great home market. If I were not afraid of trenching upon politics I might say that something should be done to get a great home market here. Lastly he referred to the complaint that had been made that he had not dealt with the artistic considerations of engineering. We have great opportunities of judging of the artistic merits of engineering just now, because there is a Bill, as some of you may know, for making a bridge across the Thames near to St. Paul's, and the artistic community are greatly exercised in their minds that the bridge should come up and give a view to those persons who desire to see St. Paul's through a vista of streets, instead of being a little further to the east and making a really good thoroughfare When the Bill came on yesterday I was absolutely surprised that nobody was there to represent the æsthete. But I do not believe any engineer in London who has really considered the problem for an instant would ever think of making the thoroughfare right up to the transept of St. Paul's. The danger would be great. The thoroughfare would be turned at right angles. But when you are merely writing to the papers and have not got to face a "Devil's Advocate" it is a very different thing. I have listened to the paper with very great interest and I apologise for having spoken so long on such an occasion.

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* NOTE BY THE LECTURER.—The eminent Leader of the Parliamentary Bar has detached the words he quotes from their context. The full phrase occurs on pages 4 and 5 *ante* and reads as follows: "The increasing intensity of life tends to widen more and more *that particular sphere of his energies in which* the only justification for his work is that it shall produce a profit upon its cost, or at the least shall not cause a drain upon other resources than its own revenues."

The Chairman :—

I will ask Mr. George A. Touche, M.P., to give us his opinion on the subject of commercial considerations in engineering. This parent Institution began very enthusiastically to consider the theoretical education and the liberal education of young engineers. As time went on technical training in colleges and institutions of that sort was added. Now we are in the throes of carrying it further in the shape of practical training. The three dimensions are not considered sufficient and the Institution has arranged a very important Practical Training Conference on practical training for young engineers, more particularly in connection with the application of practical instruction, and one of the most practical is this question. After all, the grand philosophy we have heard to-night comes back to a reasonable return on money, safety in working and use, and permanence and stability.

Mr. George A. Touche, M.P.:—

As the hour is late I will confine myself to a few observations upon the question of the relation between engineering and commercial policy which is covered by the interesting paper to which we have just listened. The author has made it very clear that he sets a high standard before those who desire to qualify themselves for the engineering profession ; they are not, he says, to be jacks-of-all-trades, but they must be many-sided in their experience and their knowledge. He does not ask you to do more than he has done himself. I have had the pleasure of knowing Mr. Thomson for a good many years, and I find that he is himself an engineer, a lawyer, a financier, an adventurer, an administrator, an organiser, an accountant, a physiologist, a capitalist, and a lecturer with an extraordinarily rare gift of lucid expression. Although he has distinguished himself in all these branches, and has founded these lectures for men who are younger than himself, he still succeeds in looking the youngest person present.

I was very glad indeed to hear of the emphasis which he laid on the need for acquaintance on the part of engineers with general commercial principles. It would be perhaps presumptuous for me, not belonging to your profession, to say what engineers ought to know and what they ought not to know, but if I were audacious, and were to venture an opinion, I think I should be inclined to say that, in these times, they are the last people who can afford an attitude of indifference and contempt towards commercial considerations. There may be engineers who think differently: if there are, they probably belong to that era of pyramid building when they were able to rely upon labour secured by the compulsion of authority, and to show complete indifference to cost. But very few engineers can do that nowadays, and if there are any engineers who still have that point of view, then I have no hesitation in saying they belong to the pyramid era, and ought now to be placed amongst the mummies.

It seemed to me that the author, in his address, was not free from that rather superior tone which we poor ordinary mortals have been taught to expect from civil engineers. He seemed, notwithstanding his own commercial success, to have a lingering feeling that the introduction of the question of profit was the introduction of a rather sordid element, but he suggested that the profit might be condoned if it were merely incidental, that is to say, if the undertaking did not exist for the purpose of making a profit, but the profit were made incidentally in connection with some great engineering conception. Then I observed the expression that commercial knowledge "is no discredit to the engineer." Again I would be inclined to go further, and say that the absence of commercial knowledge is a discredit to an engineer, and that, without it, his work would probably be as sterile as that of the pyramid builders to which reference has been made to-night. I think the author feels that, too, and recognises that commercial knowledge is essential to the engineer, but he probably feels it to be such a new proposition here that he must introduce it with great gentleness and delicacy. His paper was full of practical suggestions, but he seemed most tender of the tradition that the question of profit is a subordinate question hardly worthy of consideration by members of such a distinguished profession. All these suggestions are put before you in a very delicate way, as if they were not really part of the duties of civil engineers at all, but trespassed on the functions of inferior organisations.

It is very desirable, in the interests of civil engineers, that you should wipe away the tradition, which undoubtedly exists, that you, as civil engineers, are not greatly concerned with questions of commerce and profit. I have met people in the City of London, highly intelligent people, who still cherish the delusion that the civil engineer is the last person in the world you should talk to upon a commercial subject; they are quite willing to talk to mechanical engineers and electrical engineers, because they think they come into contact with the realities of life and commerce, but they consider they are trespassing upon the indulgence of the civil engineer when they go into such matters. You want to abolish that idea. It means a loss to your profession. Personally, I have never been able to discover where the dividing line is between the civil engineer and the mechanical engineer; I have never understood where the business of the one ended and that of the other began. I was endeavouring to-night to find out from Dr. Tudsbery what the distinction was, and he tells me that no man alive knows. Engineering and commerce are like husband and wife—they ought not to be divorced. The elements of engineering—the element of permanence, the element of efficiency, the element of safety—which I believe is the underlying element in all engineering—are essentially commercial elements. Therefore I would venture to say, speaking as what my friend on my left would call a bit of an accountant and one who has had some experience of the commercial side, that the commercial aspect of engineering should never, under any circumstances, be forgotten.

The commercial aspect divides itself into two parts, but I am not going, at this late hour, to take up your time by discussing them: the correct anticipation of the cost of construction, and estimates of revenue in relation to working expenses. If time permitted I would point out, from my own experience, some of the difficulties which beset engineering in these two departments. I would do so, not with a view of discouraging those who are embarking on a great profession, but rather in order that you may take warning from the disasters which have occurred to engineering enterprises and to those who have embarked their money in enterprises which were founded upon the opinions of engineers, with a view to avoiding those pitfalls yourselves in the future. At this late hour I feel I should be trespassing too far upon your indulgence if I were to do that, but one thing I would say to you from the point of view of the City and finance, and it is this: We do not want everything to be dominated by what I think the author called the consideration of cheapness at any cost. We want you—and I am talking now to those who will probably be the great engineers of the future—when you make your estimates of costs of construction, to give estimates that can be relied upon. Do not be afraid of making full provision for all necessary costs, but at the same time do not do what some engineers do, scare investors and capitalists by putting the loads on unnecessarily. The essential point to the commercial and financial mind is that the estimate of the engineer should not be misleading. It is because these estimates have often been misleading, largely through the difficulties of calculating the risks and the accidents in connection with the work, that many hesitate to start new enterprises, however desirable they may be.

You have been told to-night to give due weight to imagination in your work, and Mr. Balfour Browne has said that in his experience—and he possesses an unrivalled experience—a great many engineers allow too much imagination in their work. I should like you to apply that element of imagination in anticipating, not so much your great triumphs, but the difficulties and the risks which lie in the way of their achievement. Apply your imagination in conjuring up every possible variety of accident and risk which you would be called upon to face. In that way, and in that way only, you will be able to avoid the pitfalls which beset your profession. I quite agree that in every business there is scope for imagination, but in your profession especially there is scope both for imagination and romance. Also you want optimism. I do not think there is any profession where optimism is more desirable or required. It was the optimism of great engineers in times past which enabled them to a large extent to alter the face of the habitable world, and which has done more than anything as a civilising influence. We were told, in that quotation from Lord Goschen, that the antithesis of imagination was detail; and I should like your optimism and enthusiasm, when you come to undertake practical work, to be tempered by the analysis of detail, by attention to the thousand and one difficulties which lie in the way. Study to be reliable. I have found eminent engineers guilty of even arithmetical errors. I have never found Mr. Frame Thomson guilty of those arithmetical errors, because he carries an extraordinary calculating machine in his pocket, from which he is able to produce at a moment's notice results which no chartered accountant in the City of London can for one moment cavil at.

Mr. Hart (*Secretary of the Committee of London Students*) :—

Before we adjourn I should like to call upon you to pass a very hearty vote of thanks to Sir James Inglis for taking the Chair here this evening, and for the very kind remarks he has made to us.

The motion was carried with acclamation.

The Chairman :—

I thank you.

The Meeting then terminated.

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Author Thomson, Frame

Title The commercial and technical relations of engineering

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